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Estimation of Resection Volumes in Lesional Epilepsy Surgery

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Summary: An MR-based method for measuring resection volumes in lesional epilepsy surgery is described. The volume of the preoperative lesion, the resection cavity and, as a result, the volume of the brain surrounding the lesion resected during surgery have been calculated in 13 patients.

Index terms: Seizures, complex partial; Surgery, resective; Brain, measurements; Magnetic resonance, technique

Surgery for medically intractable lesional epilepsy is frequently highly successful and there is a wide range of surgical techniques being used for management of epileptogenic lesions (1–17). Despite this there are a number of unresolved issues. One major point of contention is the optimum volume of brain resection required for seizure control, while minimizing the neurologic and psychological sequelae. Unfortunately there is often a paucity of information about the actual surgery that has taken place and a degree of uncertainty in the subjective descriptions of operations; the terms "lesionectomy," "subtotal lobectomy," and "stereotactic craniotomy and lesion removal" are all used, often interchangeably. We therefore describe a method for measuring the amount of brain resected during lesional epilepsy surgery using magnetic resonance (MR) imaging, with the aim of providing a more quantitative and objective basis for comparing different surgical techniques.

Patients and Methods

MR was performed on 13 patients undergoing surgery for medically intractable lesional epilepsy. Eight were male and 5 female. The mean age was 37 ± 12.3 years (range, 17 to 54 years). The lesions were cavernoma (n = 5), dysembryoplastic neuroepithelial tumor (n = 4), low-grade glioma (n = 3), and unknown (n = 1). This last patient (case 11 [see Fig 3]) had undergone a Morrell procedure (ie, multiple subpial transections of the overlying cortex without brain resection [18]) for an unresectable lesion situated in the motor cortex. All other patients underwent some form of resective surgery.

Volumetric MR was performed on a 1.5-T unit before surgery and again approximately 3 months after surgery. Identical sequences were used on both occasions. The volumetric imaging protocol has been described previously and validated in some detail (19, 20). In brief, it consisted of a T1-weighted volumetric sequence without contrast performed in the coronal plane, using a spoiled-echo gradient technique. Contiguous thin (1.5 mm) sections were obtained of the entire head, with a 35/5/1 (repetition time/echo time/excitions) pulse sequence, flip angle of 35°, and a matrix size of 256 × 128. In addition, other conventional diagnostic imaging sequences with and without contrast were used, resulting in a total scanning time of 30 minutes.

Image analysis took place in the scanning suite on an adjacent workstation. In particular the volumetric images through the operation site were studied. In the preoperative scan, the lesion margin was outlined manually with a tracker ball–driven cursor (Fig 1). Any hemosiderin or perilesional gliosis was not included (although it is easy to do so using this technique, if required). The enclosed area was then automatically calculated by pixel counting in each section. Summation of the lesion areas in all the sections through the lesion allowed the total lesion volume to be calculated (by using a multiplication factor of 1.5, the thickness in millimeters of the contiguous sections). In the postoperative study the operation site was examined, again in the volumetric sequence. The resection margins were outlined in each section (Fig 2) and the total resection volume obtained. If any residual lesion was seen, it was outlined and the volume calculated. Knowledge of the original lesion volume and any residual lesion allowed the volume of brain resection to be calculated by subtraction.

Results (Fig 3) and Discussion

It is essential for both the preoperative and postoperative studies to be performed in identical ways because a major part of the analysis relies on comparing the lesion and resection

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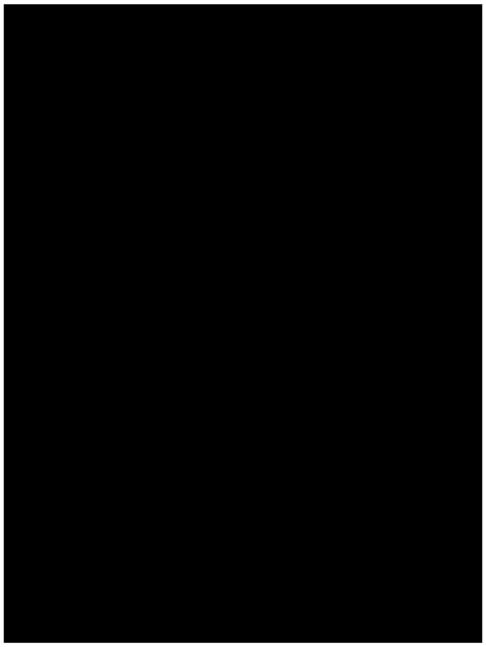

Fig 1. T1-weighted 1.5-mm-thick MR image from the volumetric sequence of the preoperative scan. The lesion has been outlined manually with the cursor and the area given automatically by pixel counting. Summation of all the areas ×1.5 will define the lesion volume.

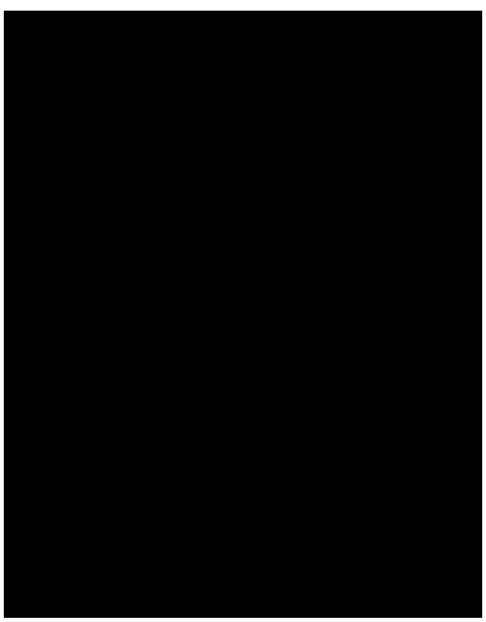

Fig 2. T1-weighted 1.5-mm-thick MR image from the volumetric sequence of the postoperative scan. This study has been performed on the same patient as in Figure 1. Exact superimposition of each section between the two studies is not necessary and the scan plane need not be identical (any plane could be used). Errors from partial-volume effects and low-area sampling frequencies are minimized by using thin and contiguous sections. The resection margin has been outlined using the manual cursor.

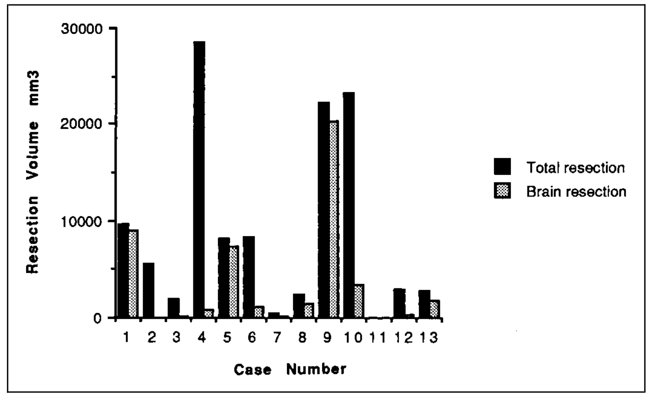

Fig 3. Volume of surrounding brain resected plotted with total resection volume in each case (volumes estimated to the nearest 100 mm^3). The two parameters are not directly related and apparently large resections may be accompanied by minimal resection of the surrounding brain because of the size of the lesion, as seen for example in case 4. In contrast, in case 5 a much smaller lesion has been removed as part of an en bloc resection of brain. Hence the amount of brain tissue removed is considerably more than in case 4.

volumes. However, because of the thinness and contiguity of the volumetric sections the area sampling frequency is high, and thus the planes of the two coronal scans need not be identical for accurate volume calculations. In practice these planes are very similar because of the constraints of a comfortable head position within the scanner head coil.

Using our technique, we have been able to assess the completeness of lesion resection and, if the resection has been incomplete, calculate the proportion of the lesion which has been resected along with the volume of the surrounding brain tissue. This information is extremely valuable in comparing different surgical approaches. Although the postoperative clinical result is determined by seizure outcome and by any neuropsychological deficits, there are currently minimal data about how important the different aspects of the surgical resection are in affected these outcome measures. Figure 3 demonstrates that the volume of brain resection is not necessarily related to the total resection volume and will depend on the preoperative and postoperative lesion volumes in the individual case and the type of resective surgery that has been performed. In case 5, for example, the patient underwent a formal lobectomy with 7400 mm^3 of brain resected; in case 6, 1200 mm^3 of brain was resected during a simple lesionectomy. In case 11 the patient had the nonresective Morrell procedure.

Chronic epileptogenic lesions such as cavernomas and dysembryoplastic tumors usually have well-defined margins on MR. This is critical for the validity of the technique, which relies on the manual definition of the lesion and resection edges. Perilesional gliosis and hemosiderin are also well seen, and by using this technique an estimate of the importance of resecting these structures along with the lesion itself may be made. Higher-grade tumors, which generally have less easily identifiable margins, can cause edematous changes in the surrounding brain, and have potential for rapid regrowth, are less suitable. We do not recommend our technique if there is brain edema, intrinsic space-occupying lesions causing mass effect, or extrinsic tumors compressing the subjacent brain.

It is important to know whether the amount of brain resected during lesional epilepsy surgery has prognostic importance in terms of seizure control or whether a minimum resection can be performed with comparable results. We are incorporating preoperative and postoperative volumetric MR into our lesional epilepsy surgery protocol on a routine basis. It is only with the detailed information that can be so provided that such issues surrounding lesional epilepsy surgery can be examined properly.

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